2019 HAWAII UNIVERSITY INTERNATIONAL CONFERENCES
SCIENCE, TECHNOLOGY & ENGINEERING, ARTS, MATHEMATICS & EDUCATION JUNE 5 - 7, 2019
HAWAII PRINCE HOTEL WAIKIKI, HONOLULU, HAWAII

BLURRING THE LINES: SPOTLIGHT ON ART AND SCIENCE IN A SUBJECT CALLED FLIGHT

HINE, JO-ANNE
QUEENSLAND CURRICULUM AND ASSESSMENT AUTHORITY
BERLIN, ROWENA
DEPARTMENT OF SCIENCE
CANNON HILL ANGLICAN COLLEGE
BRISBANE, QUEENSLAND
AUSTRALIA

Mrs. Jo-Anne Hine
Queensland Curriculum and Assessment Authority
Ms. Rowena Berlin
Department of Science
Cannon Hill Anglican College
Brisbane, Queensland
Australia

Blurring the Lines: Spotlight on Art and Science in a Subject Called Flight

Synopsis:

A case study of a cross-curricular subject that challenges junior secondary students to work collaboratively to solve a real-world problem through inquiry learning. Using knowledge and skills that transcend Art, Media Arts and Science, students are empowered to fail and employ critical thinking to learn from their mistakes. Student's perceive improvement in resilience, risk taking and reduced anxiety.

Blurring the Lines: Spotlight on Art and Science in a subject called "Flight"

Introduction

"Leonardo da Vinci took the scientific foundations of Renaissance art — perspective, light, proportions, anatomy and so on — and extended them into almost every aspect of the investigation of nature. He saw art as the ultimate form of visual knowledge, founded on an understanding of how nature works. In all his activities, he sought a core of mathematical rules – mathematics, statics, dynamics – that governed the operation of all things in nature. The rules dictated how we should re-make nature in art, science, and technology."

This quote by Martin Kemp (2017), Emeritus Research Professor in the History of Art at Oxford University, explains how Renaissance visionary Leonardo da Vinci (1452-1519) saw an intrinsic connection in his creative practice between art, mathematics and science. In da Vinci's numerous notebooks (codices), art, science, innovation and ideas are all layered and entangled. We see the codices, even now, through the cultural value placed on them, as the evidence of the creative practice of an innovator and a dreamer; a man prepared to take risks with his thinking and doing. If we were to classify him by today's ideas of knowledge, we would be hard pressed to know which discipline to slot him into. Not just a skilled draughtsman and painter (although popularly he is known best by two of the world's most famous paintings), but also an inventor, an engineer, an architect, a risk-taker and an innovator. He studied dead bodies as a scientist and drew intricate details of the interiors of them as an artist; the ultimate sci-fi designer, he came up with ideas for flying machines well before the science caught up with him. Similarly, Michelangelo's (1475-1564) expressive sculptures and his Sistine Chapel ceiling, architectural achievements and poetry found their inspiration through the observation of the natural world. Historian, Kemp, sums it up best: "The jobs of the artist and scientist were essentially the same" (Kemp, 2017).

This 500-year-old concept was the motivator behind an initial idea we shared in 2016, for a year 9 semester elective called *Flight* that championed the traits of 21st century citizens rather than siloed subject matter. The proposal was adopted by our college and has been successfully implemented in 2017 and 2018. It continues to be supported by the college and popular with students. We proposed that students would be engaged in a series of innovative and challenging learning activities crossing what are typically seen to be the boundaries of Science and Visual Art; in which flight in historical, contemporary and futuristic contexts would be explored through problem solving and project-based inquiry learning, underpinned by the idea that Science and Visual Art are linked by their inherent creativity.

In doing so we aimed to develop and encourage risk-taking and resilience skills by using inquiry-based pedagogy. This required students to experiment and trial materials and ideas, and to reflect on and evaluate their progress. The broader aim was to support students' learning in all their other subjects. We wanted to teach skills for participation in

collaborative, multi-disciplinary problem-solving activities in preparation for an interdisciplinary solution focussed future.

As part of good scientific method, we required an evidence base against which to test our proposition that inquiry learning can develop traits of risk-taking and resilience. *Flight* ran initially in 2017 with a class of 15 and again in 2018 with a class of 19. Student perceptions and experiences in both cohorts were captured to assess the success of our goals, to measure outcomes and to use the interim results to vary and improve the design of the subject to support an action research process. The positive results of the surveys, in particular the large number of students who expressed an increased preparedness to take risks and a belief that they had developed resilience, confirmed our aims were met. One student summed up her experience of the subject this way: "we were challenged to find a new way of thinking- a way of thinking that was all about curiosity and willingness to take risks" Emma, 2017. In 2018 we included questions about anxiety with the majority of the cohort citing they felt less anxious in this subject than other subjects.

Our experience shows that curriculum integration using inquiry learning as an approach to STEAM produces positive outcomes for students in developing resilience, even if students themselves have not developed the metacognition to realise this.

This paper is a case study and a reflection of our STEAM experience, which we've put together in the hope that it might inspire other junior secondary teachers to take a leap and experiment with putting the A back into STEM.

STEM and STEAM in the Global, Australian and Queensland context

In developing our STEAM subject, we responded to and challenged Australia's current emphasis on a knowledge economy in which the national and state governments are financially, culturally and institutionally directing resources at Science and Mathematics disciplines such as engineering, space science, coding and robotics, rather than The Arts. A major motivation is to arrest the long-term decline in students choosing science and mathematics subjects, and fewer university students selecting science, mathematics and engineering as a career path over the last 30 years (Australian Government, 2017). "This is a century of ideas", claimed Prime Minister, Malcom Turnbull in December 2015 as he announced the Federal Government's 1.1 billion-dollar, *National Innovation and Science Agenda*, which followed the U.S. trend of aiming to promote economic growth through funding development projects in science, technology, engineering and mathematics (STEM). *"*By unleashing our innovation, unleashing our imagination, being prepared to embrace change, we usher in the ideas boom…… It is limited only by our imagination…. we are a creative and imaginative nation…. we will have a very long ideas boom in the 21st-century" (Turnbull, 2015). This agenda remains supported by the current government.

Creativity, innovation, imagination and ideas that Turnbull claimed will fuel the ideas boom are the core of The Arts. Yet federal funding for The Arts was cut significantly in Australia's 2016 budget. Government spending on The Arts remains minimal and recently criticised by the Executive Director of the National Association for Visual Arts as offering "no vision for

the next generation of artists, nor for the adventurous audiences, awed visitors and critical thinkers who create our future" (Anatolitis, 2018).

From both scientific and arts perspectives, knowledge alone does not equal creativity and a variety of skills, knowledge and attributes are required for a productive workforce. This idea is supported by the Australian Government Productivity Commission, "There is no skills-related silver bullet" (Productivity Commission, 2017) that will future-proof the economy. Evidence from the Productivity Commission's June 2016 report, describes what it called the STEM paradox. While acknowledging the importance of STEM it pointed out, many "STEM university graduates find it difficult to gain employment after graduation." It went on to point out the significance of creativity and design skills as "they are a fundamental part of the innovation process. Skills associated with creativity are not only important for finding novel and innovative solutions, they are also skills that are unlikely to be made redundant by disruptive technology" (Commonwealth of Australia, 2016, pp. 81-83).

In 2015, all Australian education ministers agreed to the National STEM School Education Strategy 2016–2026, which "focuses on foundation skills, developing mathematical, scientific and digital literacy, and promoting problem solving, critical analysis and creative thinking skills" (Australian Government Department of Education and Training, 2018) . This led to the Queensland government's own STEM policy, *A Strategy for STEM in Queensland State Schools*, which also champions STEM and claims, "We must harness the passion for change and innovation by engaging students in STEM and providing them with the opportunities they need to develop as problem solvers, critical and creative thinkers" (Department of Education and Training , 2016).

Running through these policies is an assumption that creative thinking skills is inherently taught and learned in STEM subjects but the traditional teaching of these subjects in secondary schools is heavily content driven, especially in the senior secondary phase. STEAM offers an alternative to STEM that positions the creativity, explicitly taught in Arts subjects, within the knowledge offerings of STEM. The Queensland Advocates for Arts Education position states: "Placing The Arts into STEM signifies the value and recognition of Arts processes that are already naturally part of STEM Integrated programs and provides students with more skills, more tools and a creative approach that can be used across the curriculum" (QAAE).

Support

Recognising the similarities in processes used within Visual Art, Design and Science and interconnecting them as STEAM was a way to begin putting our own ideas into practice. As an independent school we are not bound by the state education department policy. Cannon Hill Anglican College's strategic approach to teaching and learning, called *Next Practice*, facilitates the support from the College for the implementation of our STEAM elective.

The College website describes this approach:

> Next Practice is a future-focussed approach to teaching and learning enabled by new technologies. It is characterised by engagement in relevant, authentic learning experiences which integrate the learning environment with the real world of global citizenship. (Cannon Hill Anglican College, 2018)

The Next Practice philosophy aligns with global future thinking from the World Economic Forum whose executive chairman said "We need to shape a future that works for all of us by putting people first and empowering them" (Schwab, 2016). To empower our students, we need to ensure they have opportunities to develop the core skills posited by the World Economic Forum as being most in demand in 2020. These include the top three skills for future employment: complex problem solving, critical thinking, and creativity. Creativity according the WEF jumps from tenth most important skill in 2015 to third most important skill in 2020 (Gray, 2016).

These core skills are already the essence of the processes and pedagogy used within our Visual Art classes at CHAC. With open ended inquiry-based learning and differentiated coaching of students as they work through their individual creative pathways and implement their ideas, our strength is in creativity.

What STEAM had to offer to add to this was the strength of cross curriculum collaboration and critical thinking. It is summed up by Susan Riley a U.S. expert in STEAM Education. She says:

> Our world is not divided by subject areas outside of the schoolhouse walls, so why should our curriculum be any different? Our curriculum should reflect the complexities, realities and needs of the global society in which our children live. The arts are very much a part of that…. they are tightly interwoven into the fabric of the 21st century. Our kids don't go outside and say "the sky is blue - that's art. There's a tree - that's science. (Beattie, 2016)

So, by implementing a STEAM subject we were effectively breaking down barriers between subject areas and proposing an authentic and realistic model of the way people in the workforce solve problems together. Albert Einstein famously said, "Imagination is more important than knowledge", however we see them both as intrinsic to the learning process, as he would have. Science is a process of learning, of observing and of gathering information about the way things work in order to solve problems, rather than an accumulation of facts and figures. In project-based learning, open ended questions and problems need to be addressed using creativity that often goes beyond the field of research and as such, students need to be guided to learn how to use their imagination and be creative. In Visual Art, students learn skills that can be applied to problem solving in all subjects. One way to learn to avoid preconceptions is to train the brain to see, through activities such as observational drawing.

Another creative skill is making associations between unlikely ideas. Visual artists do this all the time. If students can broaden their thinking in ways that allow their mind to make surprising and non-obvious connections between ideas then they can learn to problem-solve

more effectively and efficiently. Robert DeHaan, a renowned scientist and creative thinker stated that "preconceptions are the bane of creativity, they cause you to immediately jump to a solution, because you're in a mode of thinking where you'll only see those associations that are obvious" (Cutraro, 2012).

The college

Cannon Hill Anglican College is a P-12 school, with an enrolment of around 1100, situated 10kms to the east of the Brisbane CBD and is the only co-educational independent school in the area. It is positioned close to the increasingly valuable, riverside suburbs that began a process of transformation and gentrification 30 years ago, coinciding with the founding of the college. The growth of these suburbs has led to a narrowing of socio-cultural influences in the student body, so while the Anglican ethos encourages a sense of social justice and inclusion, the student body is predominantly of the same socio-economic grouping.

The ACARA "my school" website places the college's ICSEA (Index of Community Socio-educational Advantage) value at higher than average, with 75% of the college's students identified in the top quarter of community socio-educational advantage, which:

> shows the educational performance of students, among many other things, is related to certain characteristics of their family and school such as parental education and occupation and school characteristics such as location and socio-economic background of the students it serves. (ACARA, 2015)

This socio-educational advantage is evident in the achievements of CHAC students in Standardised testing (NAPLAN) and year 12 academic results, with outcomes above state average- 36% of year 12 students achieving an OP 1 to 5 in 2016.

The College grounds include significant park-like green spaces and a melaleuca wetland with boardwalk. The environment complements the state-of-the-art facilities in new science labs and the visual and performing arts complex. The appeal of the College is in its physical aesthetics, outcomes and its approach to learning. It really is, as it describes itself "a dynamic Christian, co-educational learning community which strives to offer a balanced and holistic educational environment, in order to develop the intellectual, social, physical, emotional, aesthetic and spiritual dimensions of each of its members" (ACARA, 2017).

It's not surprising that there is a waiting list or that families choose to pay the fees to secure their children an education of this calibre. The annual fees are on par with other independent schools of similar standing in Brisbane - mid range. Our families are not super wealthy; they work hard to put their children through school and in our experience, they want their children to achieve and to be motivated to achieve. Most of them are.

Anxiety

Students at the College learn within a caring and supportive environment, yet there is anecdotal evidence through conversations with teachers, parents and students that some students experience assessment related anxiety and stress at a level that inhibits rather than enhances their performance in the senior years.

In our own experience, we have seen how this impacts students' ability to take risks with their learning or to have a go at doing, making or experimenting in the class room because they worry that they will be perceived negatively by the teacher and other students if they have a go and fail.

Our observations are supported by national and international studies of this phenomena. Internationally, the 2015 PISA (Program for international Student Assessment) results indicated that "on average across OECD countries, 59% of students reported that they often worry that taking a test will be difficult, and 66% reported that they worry about poor grades. Some 55% of students say they are very anxious for a test even if they are well prepared" and this is worse for girls than boys (OECD, 2017). What's particularly interesting to us is the PISA finding that "countries where students are highly motivated to achieve also tend to be the countries where many students feel anxious about a test, even if they are well prepared for it" (OECD, 2017). This corresponds with our experience of - some of our very motivated students are so worried about failing that they limit their experimentation in order to limit failure and as a result they do not develop resilience or receive optimal outcomes.

In April 2017 an Australian report found that "one in four young people are at risk of serious mental illness" and that "the problems that concern them most are: depression, coping with stress, body image and school or study problems" (Mission Australia and Black Dog Institute, 2017, p. 5). These reports are supported by anecdotal evidence from school principals. One Australian High School principal estimated in a news article that up to 30% of high school students could be dealing with mental health issues. Another principal commenting on the findings, states that "we've also made sure our children are living in an environment where they're protected, and in that protection, we've not allowed them to take risks or fail at something. We've created an environment that's unrealistic" (Pianegonda & Bourchier, 2017).

In developing *Flight*, we aimed to address this phenomenon by embedding risk-taking in the teaching and learning experiences of every lesson and the assessment instruments. We anticipated and hoped that by doing this we might be able to increase the students' resilience.

Methodology and pedagogy

The subject involves students researching and experimenting with a wide array of flying inventions such as planes, drones, helicopters, paper planes, parachutes, hot air balloons and so on. They draw inspiration from nature through observing bird and insect flight and wing structure. They research great artists, scientists and inventors, entrepreneurs and investigate the way that Bernoulli's principle has led to the development of aeroplanes and space flight.

Students actively engage in learning how to be creative thinkers using a series of art and design activities, many based on the Design Minds website (The State Library of Queensland, 2018). The Inquiry Learning Model from the Queensland Senior Visual Art syllabus (Queensland Curriculum and Assessment Authority) is also a key pedagogical tool in the process through which student groups develop, research, reflect on and resolve their ideas in visual form, using visual language and expression.

Risk taking and resilience skills are developed and encouraged as students experiment with and trial their designs. Also embedded in the teaching and learning is an emphasis on reflection with an aim to increase students' metacognition. Students are given time at the end of each lesson and at the end of the course to reflect on their learning. Authenticity is embedded through the nature of the group tasks, and an excursion to an aviation college at Brisbane Airport where students interact with the real examples of flight related machinery and equipment to reinforce their learning. At the presentation of their final projects the groups address their findings and ideas to an aviation expert, who gives them feedback.

The key to our methodology in designing and implementing this subject is communication and extensive collaboration between the two of us (a visual art specialist and a science specialist), with a willingness to let go of some of the traditionally valued features of a visual art or science class (like practicing with a particular art making media to master it) so that students can spend time developing essential 21st Century skills. Breaking down silos of knowledge in a secondary school is something quite unusual in Queensland. We looked to Beane's ideas about curriculum integration to develop our approach. "In curriculum integration, the schedule revolves around projects and activities rather than subjects" (Beane, 1995).

A team-teaching approach was chosen as the approach, with the two of us both teaching the class and "owning" the students and subject. We are timetabled to attend the class on alternating days, which in practice proves to be effective due to our habit of communicating by email or face to face, with precise information about what has been achieved or needs to be achieved to meet goals and deadlines. Sometimes we both attend the class (by using our timetabled spare lessons) such as during the key content lessons or during the assessment presentation lesson. We collaborate digitally using shared OneNote and set up a comprehensive plan of the whole subject in this sharable digital platform.

The use of an art room as a teaching space contributes to the success of the outcomes and this is corroborated by student survey results. The lessons are held in a visual art classroom with tables that can be easily moved around to suit activities, easy access to art materials and equipment, including cameras and tripods for making animations. This space is a creative space in the school and by being there students are unconsciously exposed to a range of artworks and activities occurring around them. Additionally, in this physical space, we also have the support of an arts teacher aide. Scientific equipment is organised in advance by a science technician (housed in the science building at the other end of the college) and kept on a trolley in a storeroom adjacent to the art teaching space. It is worth mentioning here that the college has a one to one laptop program which all families buy into on enrolment. This policy allows for flexibility and spontaneous research and rearranging of spaces and workflow and supports the students in their inquiry learning.

To support the subject, we drew from relevant Australian Curriculum content descriptions in Visual Art, Media Arts and Science and developed assessment matrices based on the Queensland Standards Elaborations (QCAA, 2018). Report comments reflecting the pedagogy and aims were developed.

Visual Diary

Within the collaborative development of the assessment tasks and pedagogy we chose to have students use a visual diary reflecting the codices of Leonardo da Vinci. This was prompted and reinforced by recent research in Norway in which a study of 10th graders confirms that reading texts in print versus on a computer screen is better for some aspects of comprehension. This is in part due to the physicality of the object (weight, size, texture) of the book which makes it easier to retrieve information. "You need to be able to leaf back and forth through different parts of the text to see, review and comprehend relationships and contexts" (Mangen, Brønnick, & Walgermo, 2013). The researchers report that this is because paper gives spatio-temporal markers while you read. Touching paper and turning pages aids the memory, making it easier to remember where you read something. “Having to scroll on the computer screen makes remembering more difficult” (Mangen, Brønnick, & Walgermo, 2013).

Using visual diaries in the class reinforces the physicality of the book. Students are using it as a tool for their inquiry learning because of its visual and physical nature. Students are able to leaf back and forth making connections between the many different components of their learning in this subject. Their research and decision making are always at their finger-tips, not locked away in a file on a computer. Because students are involved kinesthetically in adding the contents - through cutting, pasting, drawing, writing, colouring and so on, learning is richer. The visual diary is a genuine enhancement of learning. It is primarily where the evidence of critical and creative thinking is housed and was used to assess the individual critical and creative thinking in the Project Task.

Assessment Instruments

Investigation task

This assessment task is the logical conclusion of the first unit of instruction in the course. In this unit students are introduced to critical scientific and artistic knowledge that is essential for their later problem-based learning. While this knowledge is critical to their understanding of the key concepts, it is created through collaboration with the teachers rather than delivered to them by the teachers. Using Marzano's *The Art and Science of Teaching* as a guide, we looked particularly at Chapter 4 and the way that teachers can help students to generate and test hypotheses.

Marzano suggests that "hypothesis generation and testing tasks allow students to examine their thinking regarding knowledge being learned. This stimulates major change in their understanding" (Marzano, 2007, p. 97). This is effectively achieved through problem based experimental inquiry and collaborative activities to test and explore hypotheses, materials, technologies, with critical input of knowledge from teachers as guides, to drive creative thinking when needed. For example, students were shown an example of a well shot and edited stop motion video and then after being given clues about how to keep a camera still,

they were presented with the problem of working out how to create the fluidity of the animation. This was achieved by generating and testing hypotheses and collaborating to solve problems.

The trial and error nature of this pedagogy is challenging for students. Each lesson they are asked to see if they can work out how or why something happens and to record their ideas. This challenges their understanding of learning and we believe it has made them more resilient and open to testing ideas and taking risks. They have become agentic in the learning process.

The assessment item is an investigation that required students to use appropriate and rigorous scientific hypothesis and data collection. In 2017 students had to determine the effect of propeller blade length on power output. While rigorous, it was less embedded in the teaching and learning, and we felt less authentic. This was modified in 2018 to be more authentic by housing it in the teaching unit that relates to the control of a plane in the air. It was an investigation based on the steering of paper planes to determine the effect of changing mass, wingspan, increasing drag and using different materials on the flight of the plane. Students tested hypotheses and drew conclusions based on evidence. The task remained collaborative in the data collection phase and individual in the research and report-writing phase. Students put into practice all the skills they had been developing over the course of the unit prior to the submission of the assessment item.

Project task

The second unit of work is built around a comprehensive problem-based project and is based on the inquiry model adapted from Gregory and Chapman's *Differentiated Instructional Strategies* (Chapman & Gregory, 2008, p. 161). Chapman and Gregory conclude that inquiry or research is a curricular model that engages students at their levels and interests and is therefore applicable as a task that creates differentiation opportunities for students.

In the project, groups work collaboratively following the non-linear and cyclical model of *research, develop, reflect and resolve,* to generate a problem and then solve it. They need to identify a significant, global social or environmental problem and develop a flying machine that will solve the problem. They must plan, draw and build a model of the flying machine, research the science behind it and then make an animation showing how it works or could work in the future, explaining the relevant science. This is presented to an audience. Along the way there are critical input lessons from teachers and flexible lesson sequencing that can accommodate extra time required for meeting needs of learners to reflect and revisit aspects of the project to ensure a rich understanding of the key concepts is acquired. This task is an excellent example of assessment for differentiation. Within the group experience students are able to choose the aspects of the project they wish to be responsible for depending on their interests. According to Gregory and Chapman (p.146-7), a project task encourages self-directed learning, and allows students to work at complex and abstract levels that match their skill levels while managing time and materials.

The Investigation task and the Project task are both examples of authentic assessment which, according to Tangen et al, "involves engaging students in real world tasks that allow them to demonstrate their learning and understanding" (2008, p. 50). They explain that these tasks facilitate learning by building on students' strengths, interests and prior knowledge. The learning is student-centred and encourages students to challenge themselves and their understandings. These characteristics are intrinsic in the assessment tasks in *Flight*.

Project evaluation task

In this third task the students evaluate their own and each other's projects. This encourages them to reflect on their learning and to think critically about their work. To do this effectively they need to provide reasons to support their views thus requiring a deep level of engagement in the process. Due to this rich engagement, this task acts as summary of all the learning throughout the semester and we hoped also that it might encourage the development of metacognition in the students.

Reflecting

The impact of completing the Project task and the subject as a whole is reflected on by the students in the final week of the semester. The students film themselves responding to specific questions about the subject. The resulting videos are a snap shot of what they have learned in terms of themselves and their critical thinking, empathy, resilience, collaborating, communicating and how to go about solving problems. In doing so the students provide genuine feedback on the teaching and learning program.

These videos are used to advocate for the interdisciplinary STEAM teaching at subject selection evenings and at other opportunities when we can showcase the subject. They are proof that students have been set challenging goals and will be used to assist colleagues who teach this subject in the future.

Outcomes based on student survey results

Each cohort is surveyed to help ascertain success of goals and to shape the subject based on feedback.

14 surveys were completed by the first cohort of students at the end of the semester in 2017. 19 were completed in 2018. In 2018 we added questions about anxiety and stress.

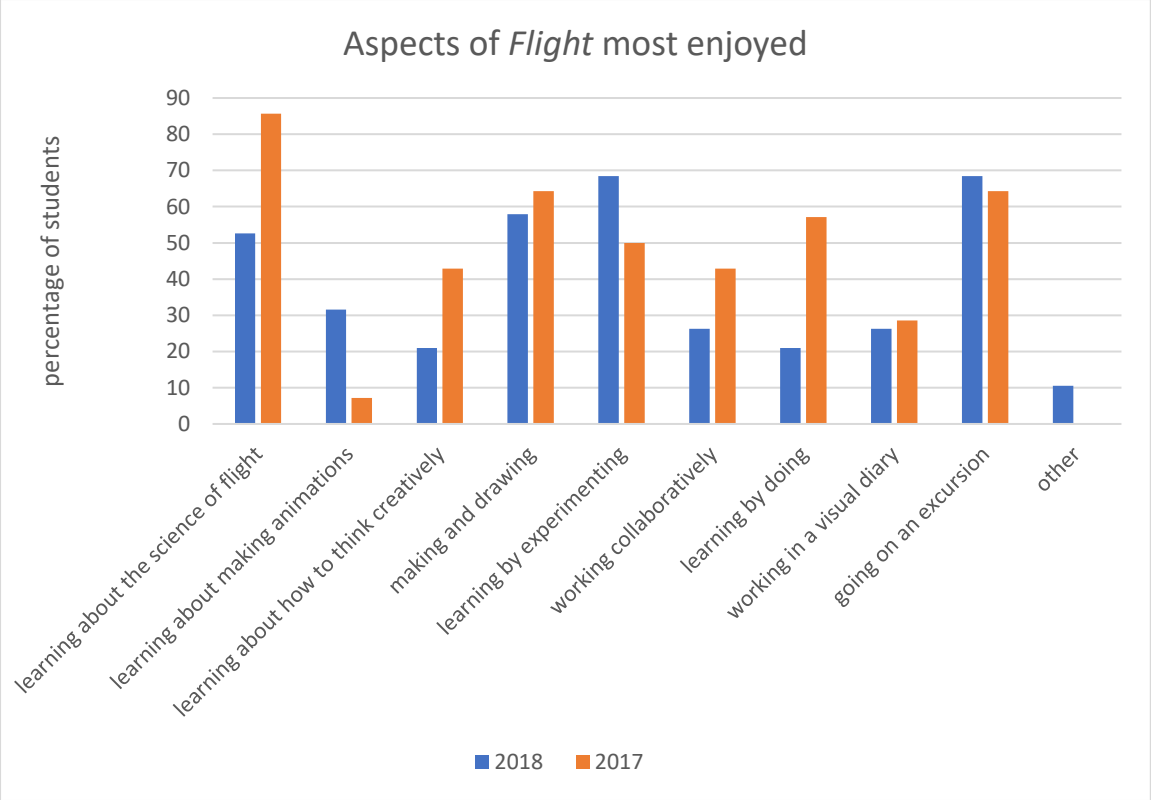

Table 1 *Aspects of Flight* ***most*** *enjoyed by students. Respondents could choose as many descriptors as they needed.*

Tables 1 and 2 reveal that a mostly positive experience was enjoyed by students in both cohorts. Students consistently most enjoyed *learning about the science of flight, going on an excursion, making and drawing, learning by doing and experimenting* (Table 1).

Even the student in 2017 who was unhappy with her group and teacher, and described the subject as *a waste of time* as one her responses (see table 3) indicated she would recommend the subject to other students and take it if a STEAM subject was offered in Year 10.

Table 3 indicates *A good mix of subjects, interesting, enjoyable, challenging and fun* are the most popular phrases chosen to describe the subject. No-one chose *boring* or *not relevant* in either year.

Both cohorts consistently would recommend this subject to others.

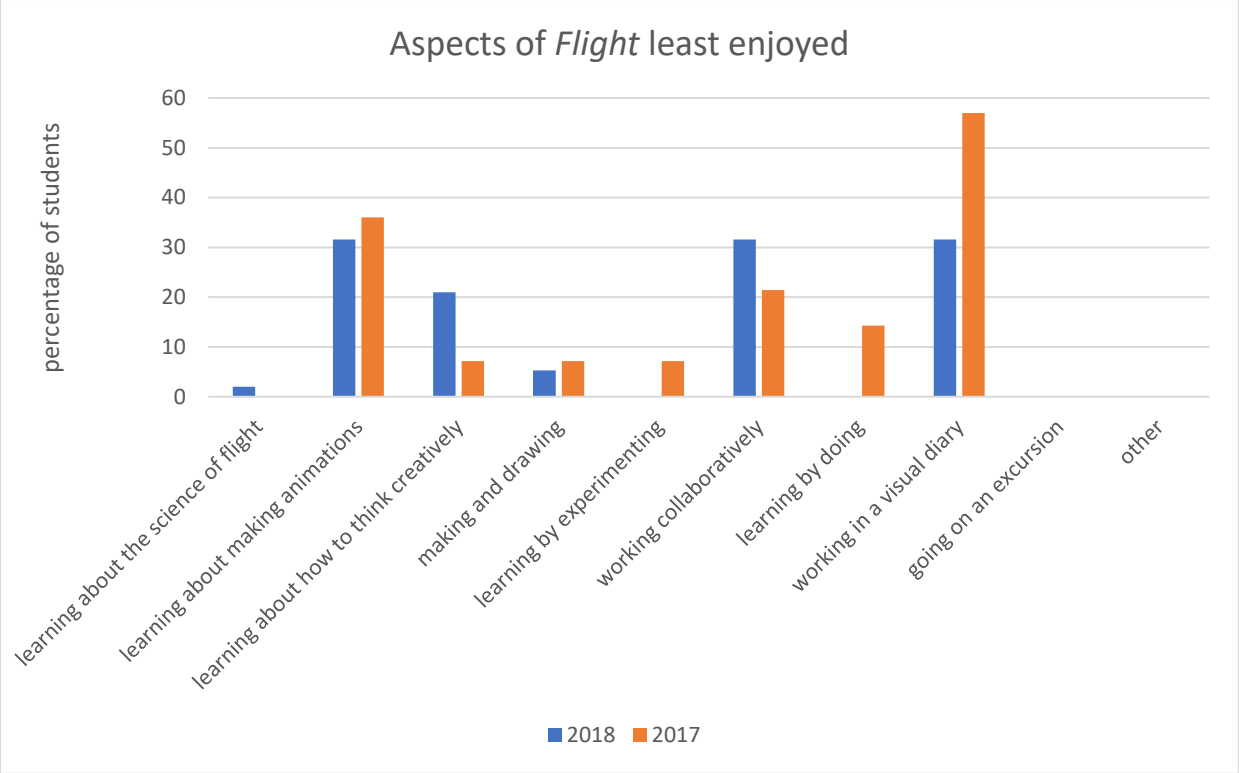

Table 2 *Aspects of Flight* ***least*** *enjoyed by students. Respondents could choose as many descriptors as they needed.*

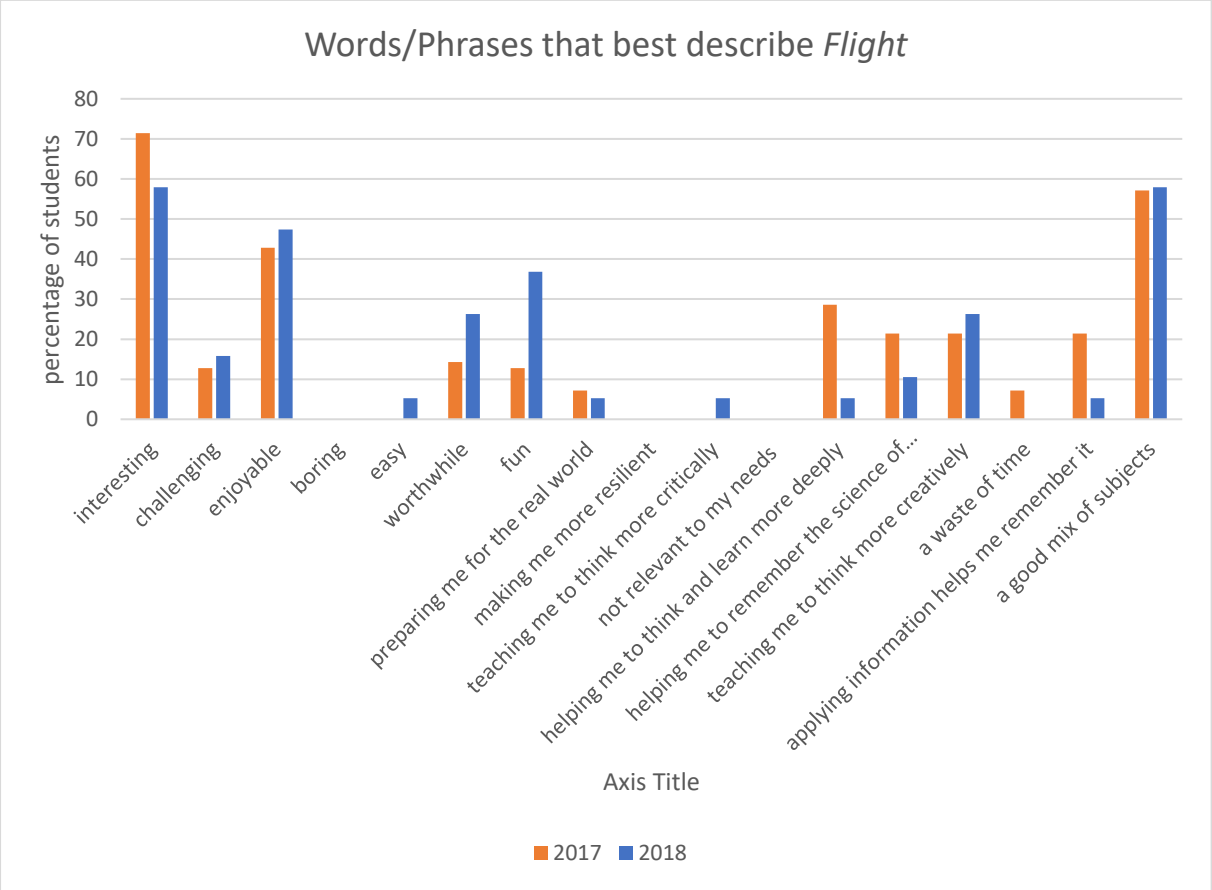

Table 3 *Students chose three words or phrases that best described the subject*

Visual Diary

There were substantial numbers (eight out of 14) who *least* enjoyed working in a visual diary in 2017 which made us consider the benefits of continuing with it.

Our teaching experience supports the idea that the students who don't enjoy using the visual diary are the ones who also don't keep very good records of their learning in a digital form either. Keeping the book is a challenge because students are forced to be more responsible for their learning; it needs to come to class and go home with them for homework. We observed that less mature students found this difficult.

We made a decision to continue using it in 2018 and structured reflection time to every lesson for the development of a reflective practice in an attempt to develop metacognition. Student feedback in 2018 is more positive with five out of 19 citing it as one of the most enjoyable and six out of 19 citing it as one of the least enjoyable aspects of the subject. So, there are still polarised opinions but they are more equal. We assume students who didn't indicate a preference either for or against are happy to use the visual diary. This seems to show the diversity of the clientele but might also indicate that the subject is more familiar to the school community and therefore its strategies are less opposed.

Animation, drawing and model

For both cohorts the Project was a challenging task. Students found it difficult, in the time frame, to organise their teams to begin the planning and filming of the animation. This resulted in less time to reflect on and resolve their work. On the other hand, most loved making and drawing. They enjoyed making the model and did learn about how to transfer their abstract ideas to two-dimensional concept drawings and detailed plans then to a physical, three-dimensional response. All involve critical thinking.

In 2018 we organised the assessment tasks to maintain the challenge and yet provide more opportunity to learn and enjoy the technique of animation by dedicating more time to this task. This resulted in the presentations being of a much higher standard because groups had prepared and practiced before presenting to an audience. Animations were more resolved and better reflected the effort that went into the models causing students to be proud of their achievements.

Collaboration

Collaboration is an essential skill that we hoped to nurture. It is challenging to collaborate if you are an anxious student who can't control the outcome of all aspects of a task. Tasks with collaboration support the aims of the course to provide authentic learning experiences.

In 2017 collaborating was *most enjoyed* by more students (42%) than those who *least enjoyed* it (22%). In 2018 it was less enjoyed with more comments about the challenges of group work. Perhaps extending the time frame for the project assessment gave students more time to reflect but also to disagree. From our observation, the main reason seemed to be a perception by students that some of them were doing more work than others. High achievers wanted to control the process but also complained that they were doing everything.

Student's comments in response to the question, *"Did you contribute effectively to the group tasks?"* indicate there were several contributing factors to uncollaborative experiences. Negative responses to the question included:

- *I did however I might need to let others do more work.*
- *Yes, kind of. We all had different ideas and it was very overwhelming.*
- *Sort of. Everyone had very different ideas and there were some arguments.*
- *I think I may have contributed a large amount because I didn't want to tell them what to do when they aren't working.*
- *Wherever possible -everyone had similar skills so everyone wanted to do the same tasks.*

It's clear that at this age (13-14) the students are still very ego driven and developing their ability to negotiate. Factoring in the dedicated teaching of effective group-work/collaboration and negotiation strategies might help to give students confidence and skills to overcome some of the issues they identified. These responses do show maturity and quite sophisticated metacognition, so potentially the fact that they have endured this experience and can articulate their response to it, may impact their ability to cope next time they are in a collaborative situation.

Critical Thinking

In 2017 more students enjoyed *learning by doing, experimenting, thinking creatively and collaborating* than did not. This indicates that they are enjoying learning using the deliberate style of pedagogy we employed to teach critical thinking skills. They are employing skills of analysis and evaluation in their learning but appear to be unaware of that. Specifically addressing critical thinking and what that means and looks like may be a way to increase their metacognition in this area. It was in their lack of the use of reflection to drive the project forward where most students lost marks in their project in 2017. In 2018 reflection time was structured more into lessons to combat this and proved to be effective. Most visual diaries were completed effectively and reflection and discussion was part of every lesson.

In 2017 no students chose *Teaching me to think more critically* as a descriptor of the subject and in 2018 only one student chose it. This is evidence that they are unaware of the link between learning by doing (trial and error) and being a critical thinker. This suggests that in the design of the teaching and learning experiences we need to specifically address developing an understanding of critical thinking. Critical thinking is however occurring through the act of trialling and failing which is dominant in the pedagogy of the subject. Learning by making mistakes, analysing them and having support and resources to try to fix them leads to developing resilience and risk-taking, which students in both cohorts overwhelmingly acknowledge has occurred during the semester.

Resilience and risk-taking

While students did not choose *making me more resilient* in Table 3 as a way of describing the subject, they do recognise it as an outcome of their learning. Table 4 shows that a significant majority in both cohorts responded positively to knowing they had made improvements in

their resilience and risk-taking. Their comments supported this and clearly express that the aims of the subject have been particularly successful in that area.

The idea of risk-taking was not well understood by the students in the survey. Many interpreted this question as if it had been a risk choosing the subject. This points to the novelty of the subject at the college. But the student comment *you have to take risks in order to improve* actually sums up our pedagogy.

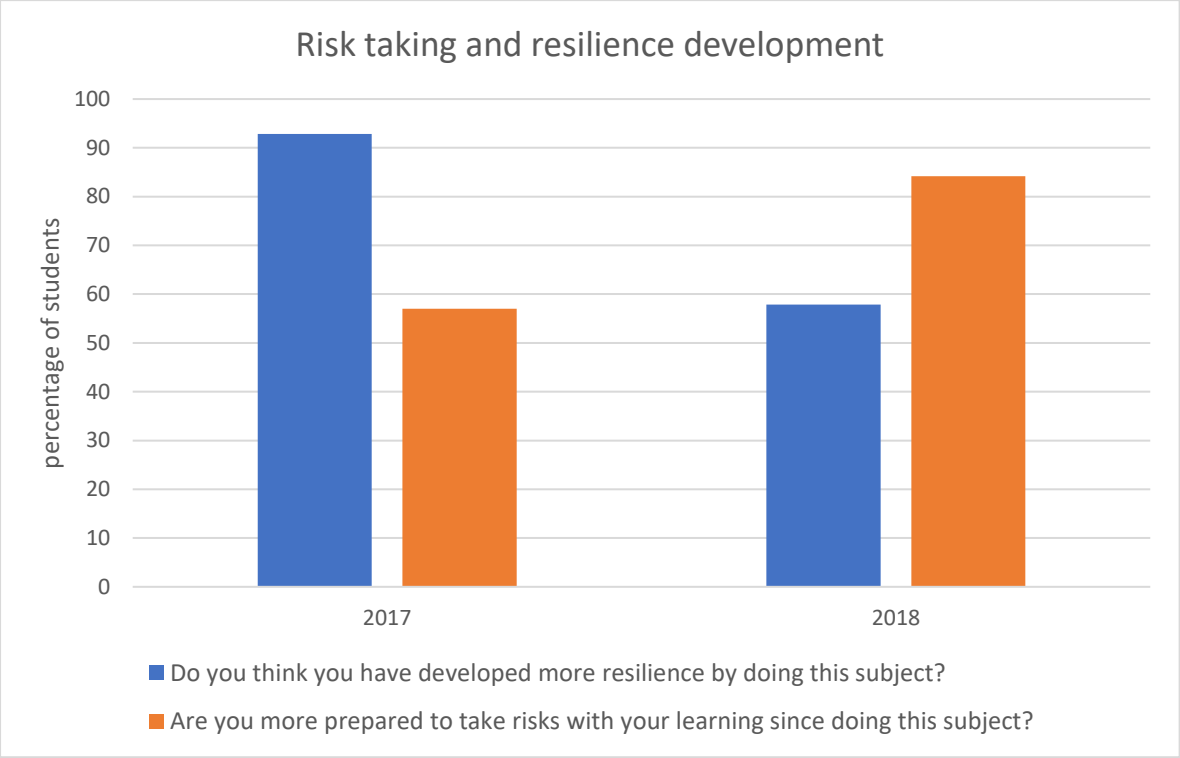

Table 4 *Student perception of their risk-taking and resilience improvement.*

Organisation/ time/ assessment

Most comments from students support that we are well organised and the resources we use to teach the course are appropriate. The art room environment is particularly conducive to making and doing, by having easy access to diverse art materials for making and experimenting which encourages and enables risk-taking.

Assessment time-frames in 2017 caused some stress to students and this was addressed in 2018 by making changes to tasks. Particularly, the project was given more time while retaining the challenge.

Authenticity of combining subjects

In 2017 and 2018 students had positive thoughts supporting the aims of the subject. They were able to articulate, in their comments, the benefits of the combination of the knowledge content and the creative processes of the subject. This shows that the subject has provided for differentiation to meet the needs of individual learners. In each cohort there was an identified student with dyslexia whose needs were met through being able to contribute their strengths to the group tasks. Comments included:

- *Good mix makes learning easier*
- *We learn the science around flight then putting that knowledge into a physical object.*
- *It helped put different abilities into other subjects*

Responsibility for own learning

Meeting a deadline as a team with a complex, multi-faceted project to present, is a challenging task. For students to meet deadlines in both collaborative tasks, they were required to take charge of their learning and be responsible for it. Each group had several parts of the project on the go concurrently and had to divide up the work. To be successful they had to trust each other and be reliable.

In 2017 this was most effective in three of the four groups, with a similar outcome in 2018. We observed that the most successful groups in 2018 surpassed the previous year's cohort in taking responsibility. In 2017 all of the students except one says they contributed to the group's project. In 2018 all responses were positive. The fact that so many students enjoyed the subject shows how much their work has meant to them and how much responsibility they have each taken for their own learning.

Anxiety

In 2018, new questions were added to the survey to ascertain how anxious students felt during this subject. In the 2018 cohort there was one student with an officially identified anxiety disorder.

15 out of 19 students responded positively to the question "*did you feel well prepared to complete the assessment tasks? Yes/ NO. Why?*

One student responded in the negative and three did not answer.

Students cited reasons such as being taught well, long time frames, information was given in class and groups worked well together and were on top of their tasks. Interestingly only one student seemed to take responsibility for their learning and cited *I studied,* as the reason they were well prepared for assessment tasks.

Two negative reasons indicated immaturity in taking responsibility for own learning or a reluctance to ask for help. They were *I feel more information could have been included about what to do* and *I found parts of the written task confusing.*

In response to "Did the assessment in this subject make you anxious?" Only one student out of 19 responded positively, while 12 responded negatively.

In comparison to other subjects, 16 students experienced ***less*** anxiety in this subject. Two students felt the same anxiety as in other subjects and one student felt more anxious than in other subjects.

These survey responses indicate that there are aspects of the subject that still cause anxiety amongst a few students, including the student with identified anxiety, who remained anxious due to poor organisational ability. However overwhelmingly the anxiety students perceived is diminished compared to other subjects.

The 2015 OECD Programme for International Student Assessment (PISA) focused on science and saw a correlation "between students' perception of the assessment as more or less threatening that determines how anxious students feel about tests" (OECD, 2017). PISA results also show that "teachers' practices, behaviours and communication in the classroom are associated with students' level of anxiety" (OECD, 2017). These ideas would support the findings from our class surveys that indicate how much fun and enjoyment students in *Flight* are having while they learn and how little anxiety they are experiencing around their assessment, which they do not perceive as threatening.

PISA 2015 also stated:

> after accounting for students' performance and socio-economic status, students who reported that their science teachers adapt the lesson to the class's needs and knowledge were less likely to report feeling anxious even if they are well prepared for a test, or to report that they get very tense when they study. Students were also less likely to report anxiety if the science teacher provides individual help when they are struggling. (OECD, 2017)

These findings support ours with only one student claiming they felt unprepared to complete the assessment task. This also supports the teaching and learning style of our project-based classroom in which the teacher moves between groups offering support and feedback on a daily basis. This individual differentiation is central to the subject.

Conclusion

The case study outlines the development and implementation of *Flight*, an interdisciplinary STEAM subject in which Year 9 students combine scientific principles of flight and artistic/ scientific problem-solving with investigative strategies, to experiment, create, design, and construct a model and an animation representative of an aspect of flight. We proposed that inquiry learning through a cross-curriculum STEAM subject can develop traits of risk-taking and resilience.

While this case study is small in scale (34 students) and limited by being set in a monocultural and privileged independent secondary college, student surveys indicate that the goals of teaching skills for participation in collaborative, multi-disciplinary problem-solving activities in preparation for an interdisciplinary, solutions focussed future were largely met. The students' perceptions of their learning and use of 21st Century skills of creativity, critical thinking, collaboration, and problem solving, risk-taking and resilience were measured in the student survey.

Surveys and teacher observation verify that *Flight* has assisted students to develop some 21st Century skills. Results showed that students understanding of critical thinking was limited. While students perceived that they didn't develop their critical thinking, they did perceive they had developed their risk-taking and resilience ability. It was apparent to the teachers that students were in fact applying critical thinking through their inquiry learning. Addressing teaching and learning about what critical thinking is and how it is applied in inquiry learning, may improve students' metacognition. Developing skills in collaborating prior to

participating in group tasks may give students more confidence and alleviate some of the stress and difficulties that students attribute to it. Survey results showed that collaboration was perceived as more challenging for many students than anticipated.

Critical thinking, problem solving and creativity have been fostered through empowering students to take risks within the safe and supportive learning environment of the inquiry-driven classroom. Trialling and failing through challenging learning experiences in this fun and enjoyable environment seem to have assisted with the development of resilience and the reduction of anxiety. Through the students' responses to the survey in 2018 it is clear that there is a connection between the development of skills in risk-taking and resilience and a perception of reduced anxiety.

Long term studies of the students, their emotional and psychological well-being, academic success and their senior schooling subject choices would be beneficial in understanding the full impact of the subject. One student from 2017 has indicated she will now study Visual Art in Year 11 and 12 because of her introduction to it through *Flight*.

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